ELSEVIER

Materials & Design. Vol. 17, No. 2, pp. 75–78, 1996

0261–3069/96 $15.00 + 0.00

PII: S0261-3069(96)00035-0

An indigenous technology for a silver brazing alloy

S.C. Dev and C.S. Sivaramakrishnan*

National Metallurgical Laboratory, Council of Scientific and Industrial Research, Jamshedpur 831007, India

Received 22 May 1996; accepted 24 July 1996

This paper deals with the development of an indigenous technology for a widely used silver brazing alloy (BAg-1). Melting, alloying, casting and processing along with the heat treatment schedules, have been dealt with. Particular emphasis has been laid on the corrosion behaviour of this alloy. Copyright © 1996 Elsevier Science Ltd

Keywords: silver brazing alloy; wetting; corrosion and mechanical properties

Introduction

Silver brazing alloys of the American Welding Society's specification are best suited as filler material for joining ferrous and non-ferrous metals, and alloys[1,2]. Of these, BAg-1 containing 42–44%Ag, 15–15%Cu, 18–22%Zn and 20–22%Cd, is an alloy for general purpose applications; and is widely used for brazing steel, copper, brass, gun metal, tin bronze, aluminium bronze, manganese bronze, silver based contacts, nickel based alloys and nickel silver of all types[3,4]. This alloy has free flowing characteristics and a narrow melting range. It is essentially an alloy for use, where joints are closely fitted, or where it is desired to employ a single brazing alloy that will be effective in a wide range of applications. The entire requirement of this brazing alloy is either met by importing or manufacturing using imported technology.

Problems are encountered during the indigenous production of sound ingots/slabs, heat treatment and processing, like rolling, wire drawing etc. for making thin sheet/wire of BAg-1 alloy. Cadmium and zinc are highly oxidisable metals and this factor plays an important role in controlling the loss of these elements during melting. Also, the wide differences in melting points and densities (*Table 1*) of the alloying elements cause problems in the production of homogeneous ingots/slabs.

A detailed experimental programme was undertaken at the National Metallurgical Laboratory to indigenise the production technology of this brazing alloy. This involved establishing the processing parameters, such as melting, alloying, casting, heat treatment and rolling into thin sheets/wires for brazing applications.

Experimental

Silver, copper, zinc and cadmium of 99.9% purity were used for the preparation of the alloy. Copper and silver were melted together in an electric resistance furnace in a clay bonded graphite crucible. Preheated zinc and cadmium were added with a cover of borax flux on the molten surface to protect them from oxidation and loss. The compositions of the experimental and imported standard alloys are given in *Table 2*.

The homogenised melt was poured in a preheated steel mould in the temperature range 700–750°C. Experimental alloys, each weighing 500 to 1000 g were made using the above procedure.

Heat treatment and processing

The cast ingots/slabs were given a certain amount of reduction by rolling them at the room temperature prior to the heat treatment, to reduce the conventional long homogenisation period (24 h) to 6–8 h at 400–460°C. The homogenised slabs/ingots were then rolled into thin sheets using intermediate annealing heat treatment.

Evaluation of properties

Wetting properties

Wettability tests for both the indigenous and imported alloys were done on copper and steel base plates by placing a cubical sample, having a length of 3 mm, at the centre of base plates, having dimensions 24 mm×12 mm×1 mm, and heating in Leitz Wetzlar heating microscope (Germany). A thermocouple was placed below the base plate and the assembly was put inside a tube furnace. A Leitz microscope was attached to the furnace to monitor the softening process in-situ, under argon atmosphere. Direct photographs of the contact angles of the alloys on the base plates at a brazing temperature (650°C) were taken and measured.

Mechanical properties

The mechanical properties, such as tensile strength, hardness and elongation, as well as the brazed joint strength for both the indigenous and imported alloys were

*Corresponding author.

Table 1 Melting points and densities of alloying elements for BAg-1 Silver brazing alloy

Element	Melting point (°C)	Density (g cm^{-3})
Silver	961	10.50
Copper	1083	8.94
Zinc	419	7.13
Cadmium	321	8.64

Table 2 Compositions of the imported and indigenous brazing alloys

	Cu[a]	Zn[a]	Cd[a]	Ag[a]
Indigenous alloy	16	20	20	balance
Standard alloy (BAg-1)	15–17	18–22	20–22	balance

[a] wt.%

determined. Instron tensile testing machine was used for tensile strength and Vickers Hardness tester for hardness.

Corrosion properties

Electrochemical studies of the imported and indigenous alloys were done using a microprocessor based potentiostat/galvanostat (PARC-273 A) in 3.5% NaCl and 1% Na_2S solutions, respectively, at a scan rate of 2 mV s^{-1} at the room temperature. A saturated calomel electrode and graphite rod were used as a reference and an auxiliary electrode, respectively. A surface area of 1 cm^2 was exposed for the test. The corrosion current (I_{corr}), open circuit potential (OCP) and corrosion rate were determined.

For the atmospheric corrosion test, standard sized, mirror finished test specimens were exposed at an angle of 45° in industrial and marine atmospheres, at Jamshedpur and the sea shore at Digha, respectively, and the corrosion rates after 30, 90 and 180 days of exposure were determined by weight-loss method. The industrial atmosphere contained sulphuroxides, carbondioxide, hydrogen sulphide, ammonia and chlorine gas. The marine atmosphere mainly comprised sodium chloride, moisture etc.

Metallographic studies

Optical microscopic studies were done on cast and homogenised samples.

Service trials

Silver based contact tips were brazed to a backing material (copper) with both the indigenous and imported brazing alloys, and tested for their endurance performance in the breaking and making of electrical circuits in railways and different steel plants under heavy current loads.

Results and discussion

The variation in the total loss of weight for different melts due to the oxidation of zinc and cadmium during the melting of the alloy are shown in *Figure 1*. The curve shows that the loss of cadmium and zinc decreases as the total quantity of the melting charges increases. An amount of 500 g and above of the charge would be economical for the melting of the alloy. The authors have also studied the effect of the size of the cadmium and zinc metal pieces to be added to the molten alloy during melting. It is found that the weight of each piece of zinc and cadmium should be 2–5% of the weight of Ag–Cu of the charge to prevent the excessive loss of cadmium or zinc. The addition of cadmium or zinc pieces heavier than that mentioned above had been found to chill the bath of the molten metal, whereas lighter pieces increase the loss of metals. It is evident from the processing steps (*Figure 2*) that the homogenisation time has been reduced from 24 hours to 8 hours by reduction, at the room temperature prior to homogenisation. Microstructures of the cast and homogenised samples are shown in *Figure 3*. It can be seen that the dendritic structure disappears on homogenisation. The initial reduction at the room temperature improves the kinetics of the homogenisation by reducing the effective diffusion distances[5].

During the processing of the homogenised slabs by rolling, it is observed that the initial reduction of the slab should not be more than 20–25% until it has been reduced by 45%. Then, with intermediate annealing in the range 400–450°C, the slab could be reduced to a thin sheet having a thickness of 0.15–0.05 mm with a 35–40% reduction, at each cycle of rolling. The physical properties of the silver base brazing alloys studied are given in *Table 3*. The solidus and liquidus temperatures, densities and electrical conductivities are also reported which are very close for both the imported and indigenous alloys. *Table 4* shows the

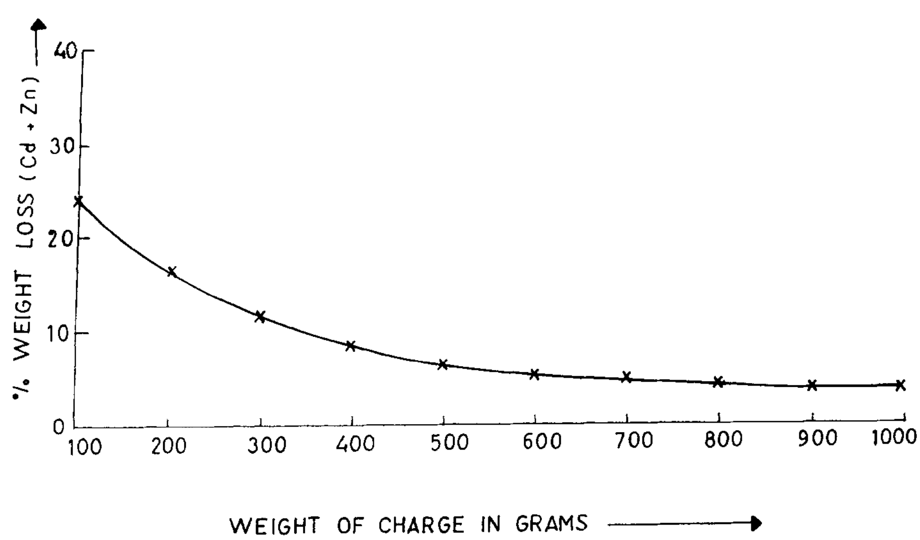

Figure 1 Variation in loss of weight of charge due to oxidation of Cd and Zn

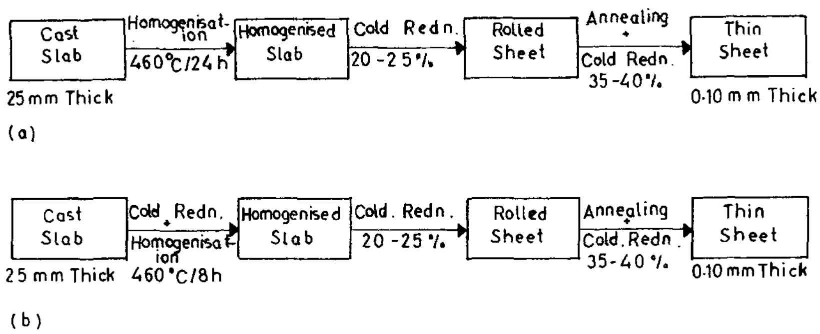

Figure 2 Processing schedule for the brazing alloy: (a) conventional and (b) modified in the present work

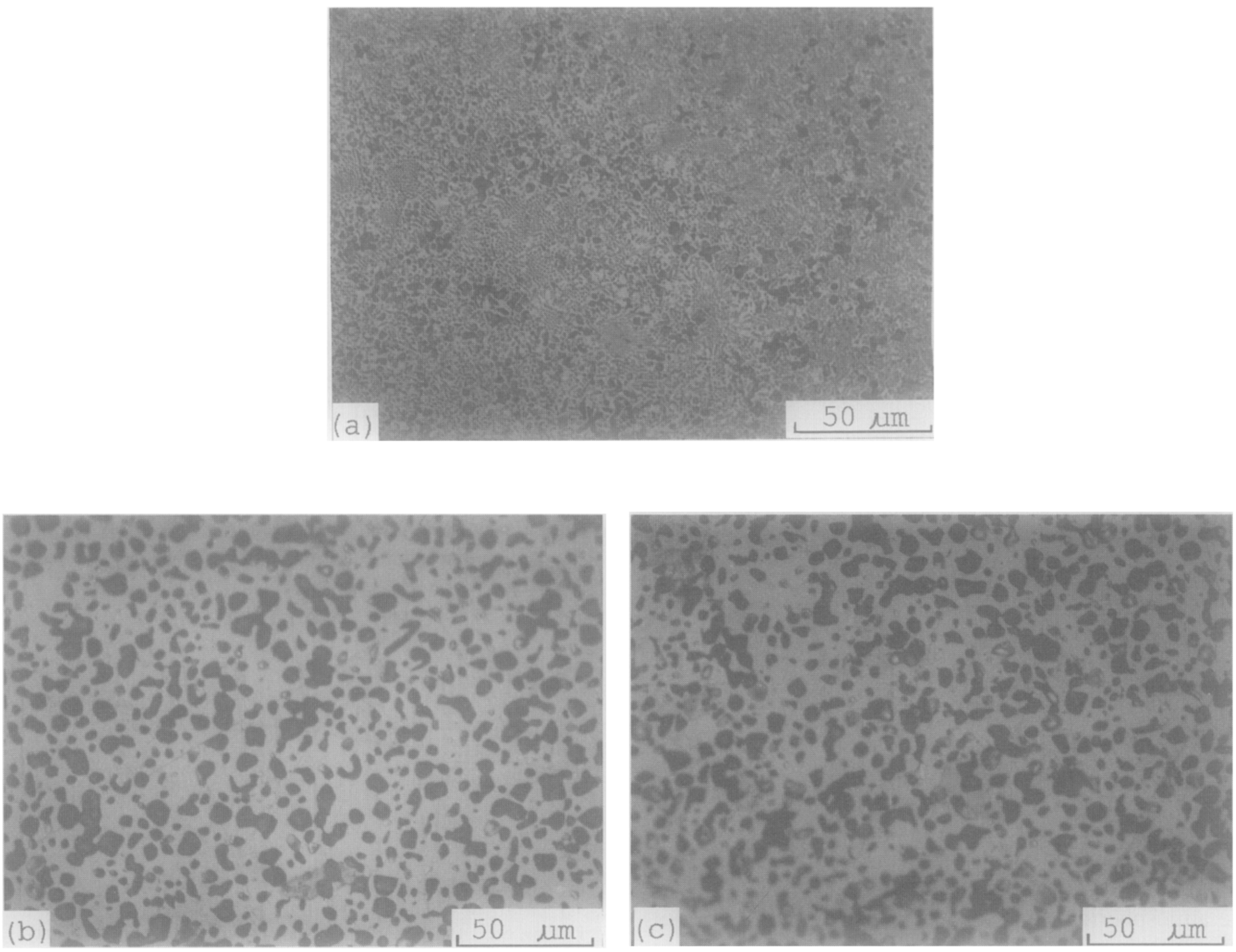

Figure 3 Photomicrographs of the indigenous brazing alloy under various conditions: (a) as cast, (b) homogenised at 460°C for 24 h and (c) reduced by rolling at room temperature prior to homogenisation at 460°C for 8 h

Table 3 Physical properties of the brazing alloy

Alloy	Temperature (°C)		Density (g cm^{-3})	Electrical conductivity (%IACS)
	Solidus	Liquidus		
Imported	610	620	9.2	25.28
Inditenous	605	618	9.4	27.30

wetting properties, such as contact angles, spreading area and wetting index. It is evident that the values are nearly the same for both the imported and indigenous alloys. Hardness, yield strength, tensile strength and elongation are shown in *Table 5*. The indigenous alloy shows better values. The brazed joints (Cu–Cu and steel–steel) were tested for mechanical properties and the values are shown in *Table 6*. It is evident once again that the values for both

Table 4 Wetting properties of brazing alloys

Alloy	Brazing temp (°C)	Atmosphere	Contact angle (°) (θ)	Wetting area [in^2 (mm^2)] (A)	Wetting index (WI)*
Imported	(a) 650	Argon	16	0.300 (192)	0.29
	(b) 650	Argon	20	0.280 (179)	0.26
Indigenous	(a) 650	Argon	18	0.300 (192)	0.29
	(b) 650	Argon	20	0.200 (186)	0.27

* Wetting index=A cos θ>0.10 shows excellent performance during brazing

Table 5 Mechanical properties of the brazing alloys

Alloys	Hardness (VPN)	Yield strength (MPa)	UTS(MPa)	% Elongation
Imported	100	180	350	30
Indigenous	105	200	400	35

Table 6 Mechanical properties of the brazed joints

Alloy	Impact strength (Kg m)	Shear strength (MPa)	UTS (MPa)	Location of fracture
Imported	[a] 2.8	120	300	Joint
	[b] 3.0	100	170	Base metal
Indigenous	[a] 3.0	120	350	Joint
	[b] 3.0	110	180	Base metal

[a] for steel to steel and [b] for copper to copper joints

Table 7 Polarisation data of the brazing alloys

Alloy	3.5% NaCl solution			1% Na_2S solution		
	OCP(−V)	I_{corr}	Corrosion rate (m y^{-1})	OCP(−V)	I_{corr}	Corrosion rate (m y^{-1})
Imported	0.430	1.33	0.435	1.420	10.30	3.40
Indigenous	0.4366	1.318	0.433	1.412	10.10	3.35

Table 8 Atmospheric corrosion test results for the brazing alloys

Alloy	Exposure time (days)	Corrosion rate (m y^{-1}) Industrial atmosphere	Marine atmosphere
Imported	30	0.0865	0.339
	90	0.0520	0.234
	180	0.0176	0.198
Indigenous	30	0.0880	0.343
	90	0.0500	0.230
	180	0.0170	0.203

the imported and indigenous alloys are similar or the indigenous alloy gives better values. *Table 7* gives the polarisation data in NaCl and Na_2S solutions at the room temperature. Appreciable changes in the corrosion properties of the alloys are not observed.

The atmospheric test results for 30, 90 and 180 days of exposure in industrial and marine environments are given in *Table 8*. It is evident that both the imported and indigenous alloys have similar corrosion behaviour.

Conclusions

The indigenously produced silver based brazing alloy possesses similar mechanical and physical properties as the imported BAg-1 brazing alloy. The alloy was tested in industrial and marine atmospheres along with the imported alloy, and both were found to be equally corrosion resistant.

The brazed joints with indigenous alloy tested for tensile strength showed that the strength properties are better than those of the imported alloy.

Recommendation for further work

Further work could be undertaken to study the wettability characteristics of the alloy incorporating some microadditions, like indium, bismuth etc. Detailed corrosion studies could also be studied under longer exposures.

Acknowledgements

The authors wish to extend their thanks to the Director, National Metallurgical Laboratory for his kind permission to publish this work and to D.K. Basu for carrying out the corrosion tests.

References

1 Dev, S.C., Basak, P., Singh, Inder, Dubey, R.K. and Mohanty, O.N., *J. Mat. Sci.*, 1992, **27**, 6646.
2 Barnett, O.T., Filler metals for joining. Chapman and Hall, London, 1959, p. 205.
3 Indian Standard Specification for Brazing alloys, IS 2927-1975, 1st Dec., 1975.
4 Chamer, E.S., Silver—Economics, Metallurgy and Uses, eds A Butt and C. D. Coxe. Kriger, Hintington, 1975, p. 386.
5 Shewmon, P.G., Transformation in Metals. McGraw Hill, New York, 1969, p. 42.
6 Feduska, W., *Welding J.*, 1959, **38**(3), 131s.
7 McDonald, M.M., Heiple, C.R. *et al.*, Supplement to Welding J., Oct. (1989) 391s.
8 D. L. Keller, M. M. McDonald *et al.*, Welding J., Oct. 1990, 33.